How to Delineate Watersheds in ArcGIS for Desktop

This tutorial will show you how to delineate watersheds from the LiDAR Image Services located at: http://lidar.geodata.md.gov/imap/rest/services, using ArcGIS for Desktop (requires Spatial Analyst extension).

What is a watershed?

A watershed is an area of land containing common hydrologic features that eventually flow into a single larger body of water, such as a river, lake or ocean.

When is it appropriate to delineate a watershed?

The health of the upper regions in a watershed affects the quality of water downstream. Understanding where the watershed lies can assist in determining possible contamination sources and developing plans for conservation and resource management.
Users who require the raw data, countywide DEMs are available for download from the MD iMAP LiDAR Download page.
First we will need to connect to the MD iMAP Maryland LiDAR Topography Server, for more information please follow this link to learn How to Access Maryland LiDAR Image Services.

Tutorial Scenario

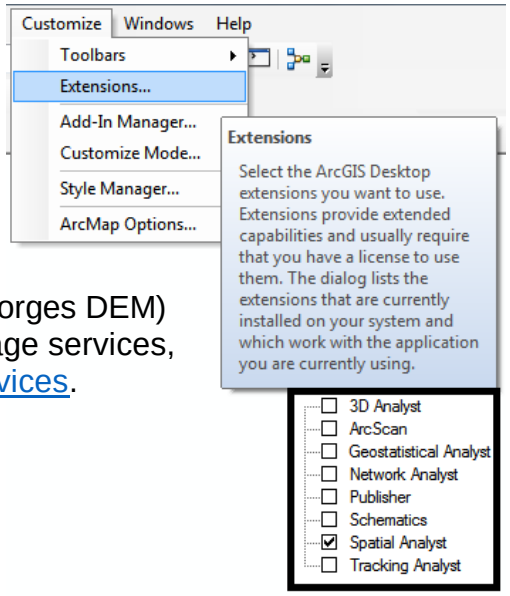
In this tutorial we are assuming the following hypothetical scenario:
Determine the watershed upstream of gauging station at coordinates (-76.815145, 38.868287) Prince Georges County, Maryland.

- Create Pour Point Feature Class
- Flow Direction (Spatial Analyst)
- Sink (Spatial Analyst)
- Fill (Spatial Analyst)
- Flow Direction (Spatial Analyst)
- Flow Accumulation (Spatial Analyst)
- Snap Pour Point (Spatial Analyst)
- Watershed (Spatial Analyst)

Create Pour Point Feature Class

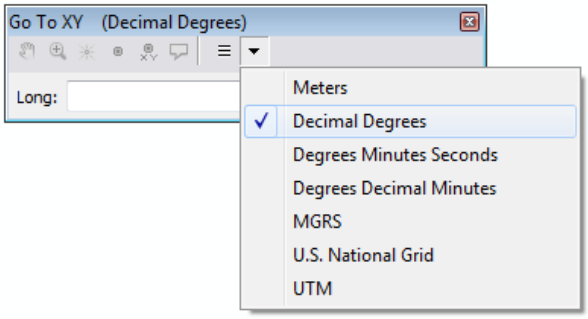
1. Open ArcMap

2. Check out Spatial Analyst Extension:



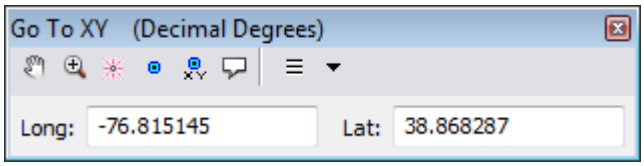
3. Add the desired Image Service to your map. (Prince Georges DEM)
   For more information on accessing Maryland LiDAR image services, please read [How to Access Maryland LiDAR Image Services].

4. Open the Go To XY ( ) tool.
   Select the Decimal Degrees units from the dropdown:



5. Create a hypothetical gauging station at coordinates:

   (-76.815145, 38.868287)



   Select Add Point ( )
   Click Zoom To ( ) to center the display extent on the newly added point

6. Extract a local copy of the DEM. Set extent to 1:18,000 for the extraction.
   For more information on the image service extraction process, please read [How to Extract from Image Services in ArcGIS for Desktop].

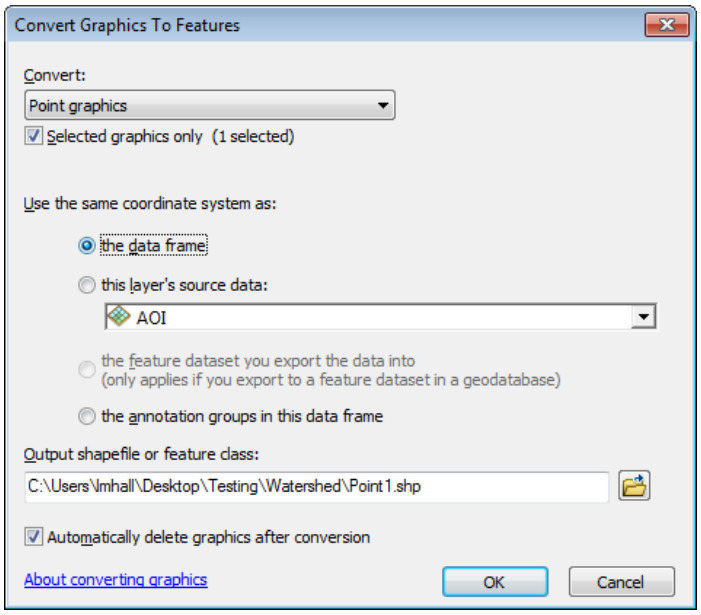
7. Open the Draw Toolbar in ArcMap
   Using the Select Elements tool ( ); highlight/select the added point.

8. Select the Drawing dropdown menu Convert Graphics to Features

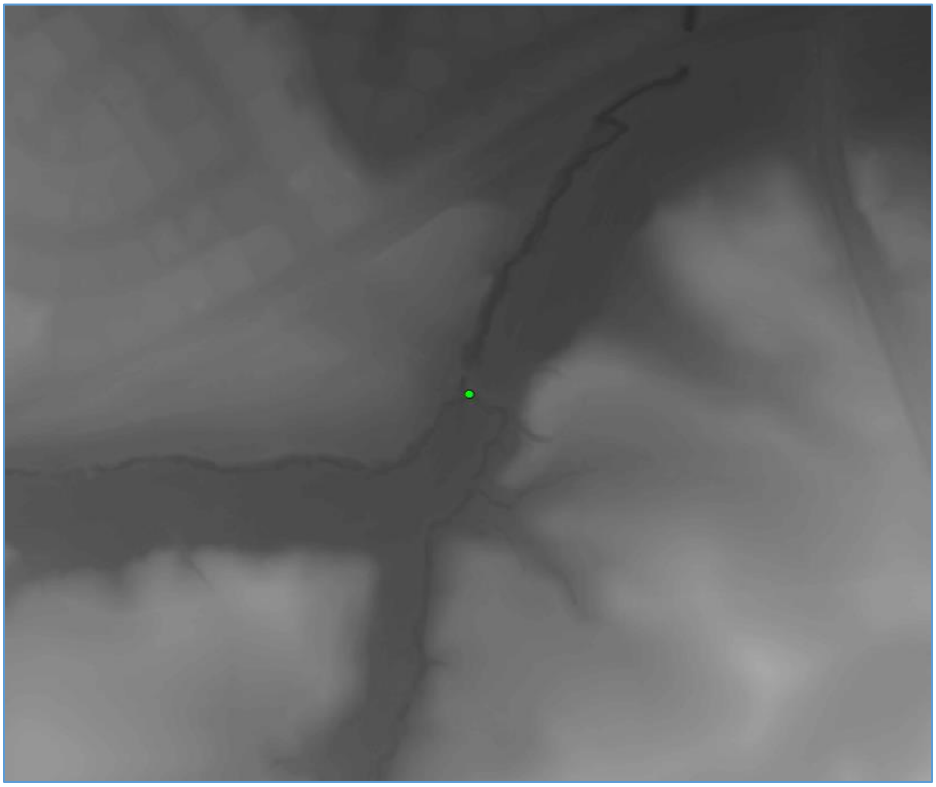
   Convert: Point Graphics
   Coordinate System: This layer's source data
   Output: …\ Testing\Watershed\Point1.shp

   Automatically delete graphics after conversion

   Click OK



   Add layer to map: Yes



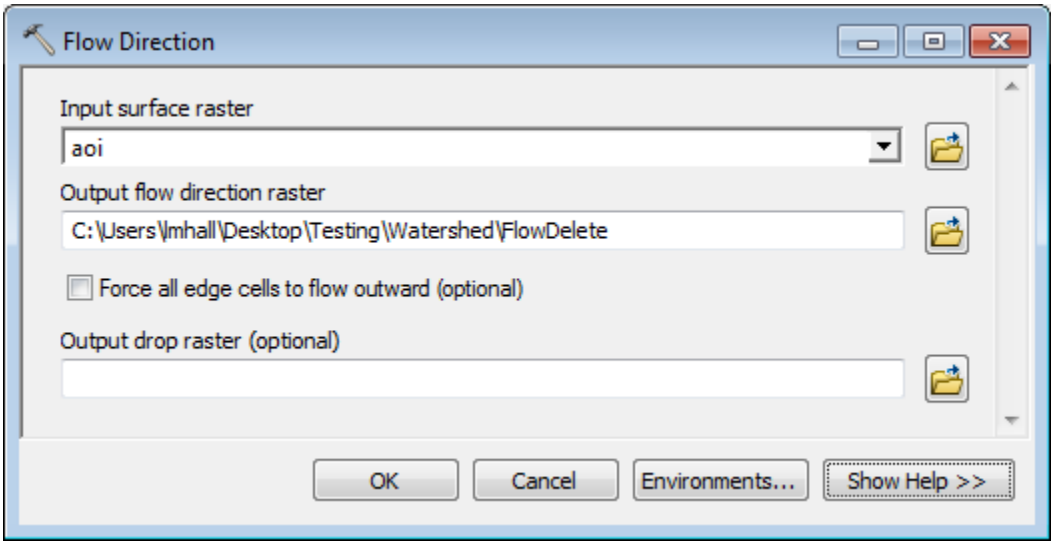
Flow Direction

Now that our pour point feature is created, we need to process our DEM for the watershed.

Our first step it to determine the direction of flow for each cell in our dataset. The DEM is likely to contain erroneous depression, therefore we must use the Flow dataset to locate sinks and fill them.

1. Search Tool > Flow Direction (Spatial Analyst)

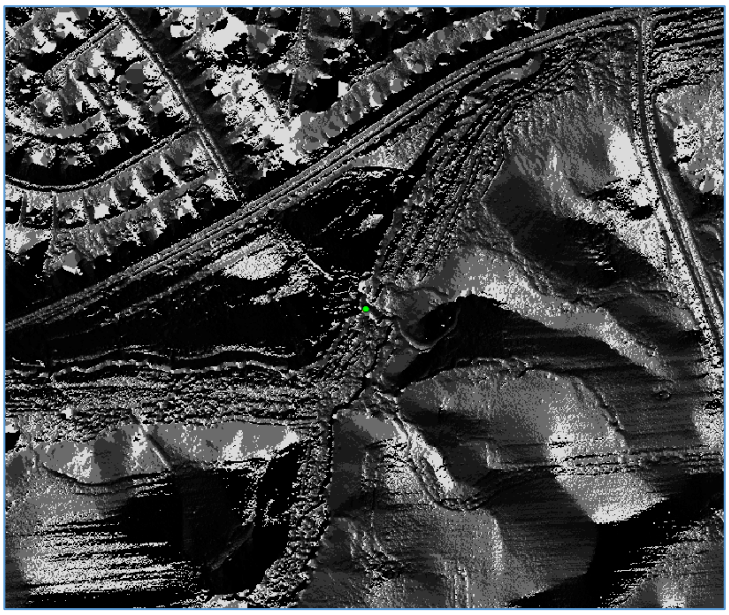
   Input surface raster: 'aoi'
   Output flow direction raster: …\Testing\Watershed\FlowDelete



   Click OK

This dataset will be deleted after we run the next tool, (Sink).

Once the erroneous depressions are filled from the Sink tool, we will re-run our Flow Direction to continue our watershed analysis.

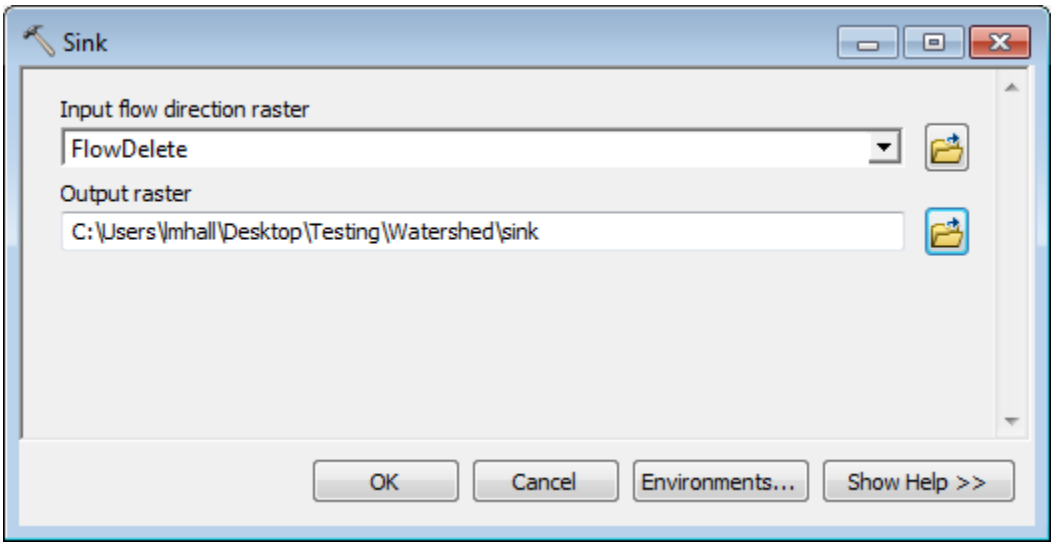


Sink

1. Using the output above - 'FlowDelete', we can generate a sink dataset.

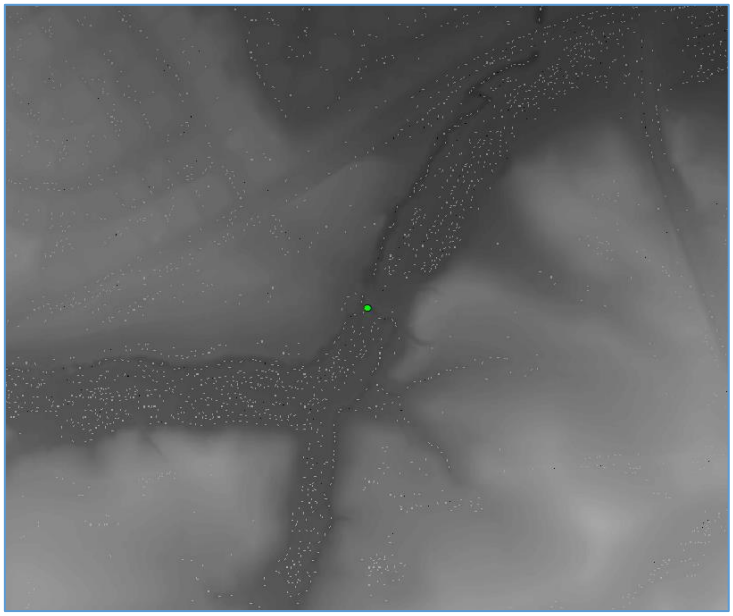
   Search Tool> Sink (Spatial Analyst)

   Input flow direction raster: FlowDelete
   Output Raster: …\Testing\Watershed\sink



   Click OK

   Examine the output Sink.



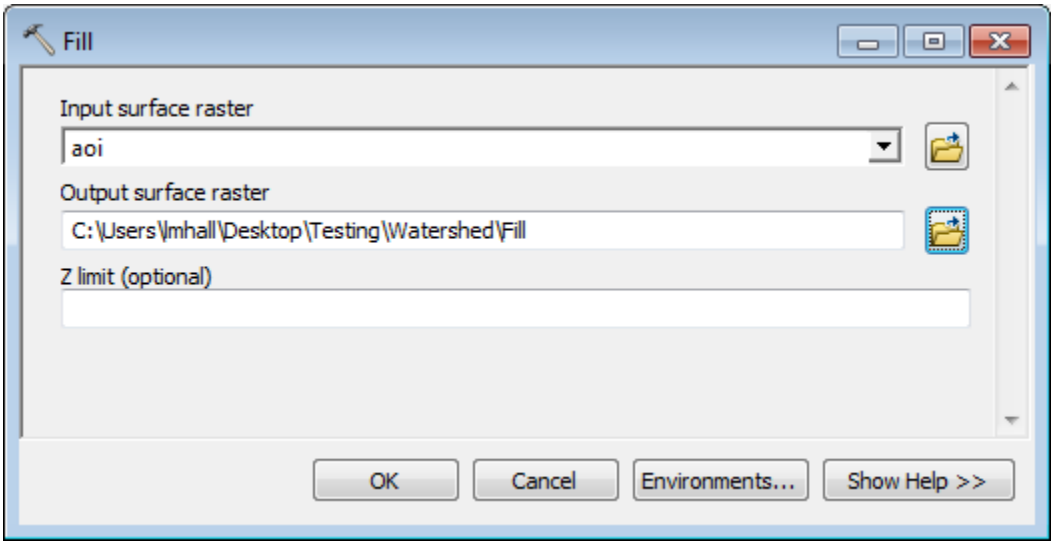
   A more detailed analysis can be performed where the sink depths would be limited in order to prevent actual basins from being filled.

   However that requires an extremely time intensive iterative process and therefore will not be discussed in this tutorial.

Fill

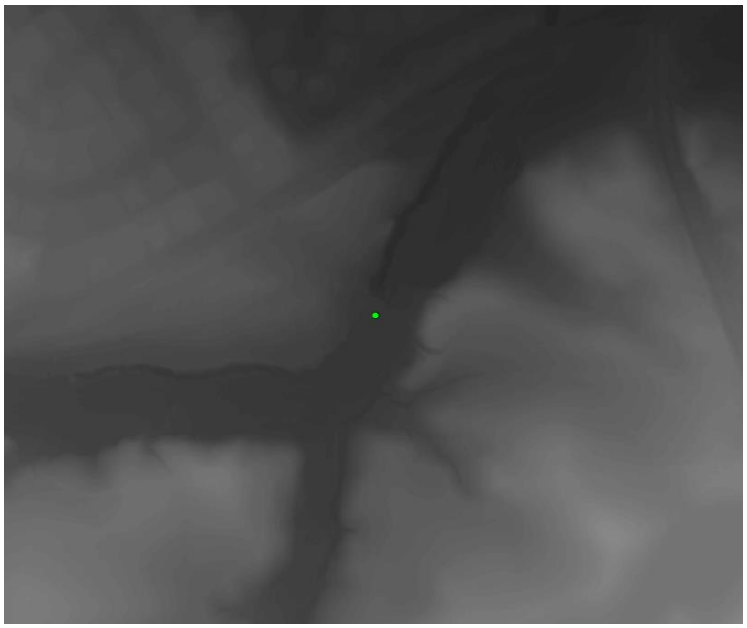
1. Search Tool> Fill (Spatial Analyst)

   Input Surface Raster: ‘aoi’
   Output Surface Raster: …\DEGIS\Workshop\Outputs\Module_4\Fill



   Click OK

   The output from ‘Fill’ should look like the original DEM; you should notice a few changes however. The new dataset has had depressions filled in order to generate a usable flow direction dataset.

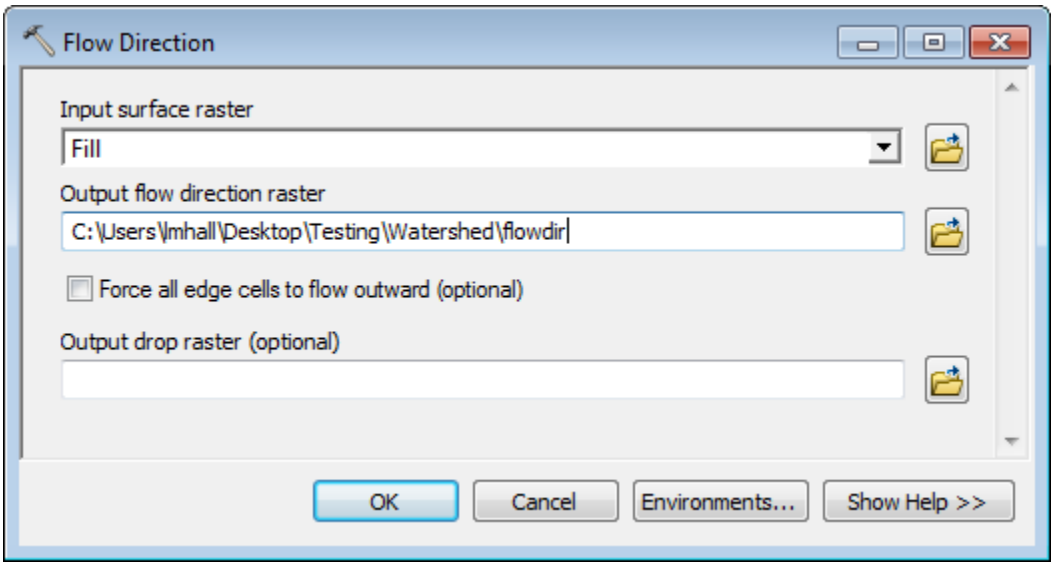


Flow Direction

1. We need to create a new Flow Direction raster from our recently filled DEM.
   *Delete 'FlowDelete' dataset from your output workspace.

   Search Tool> Flow Direction (Spatial Analyst)

   Input surface raster: Fill
   Output flow direction raster: …\Testing\Watershed\flowdir



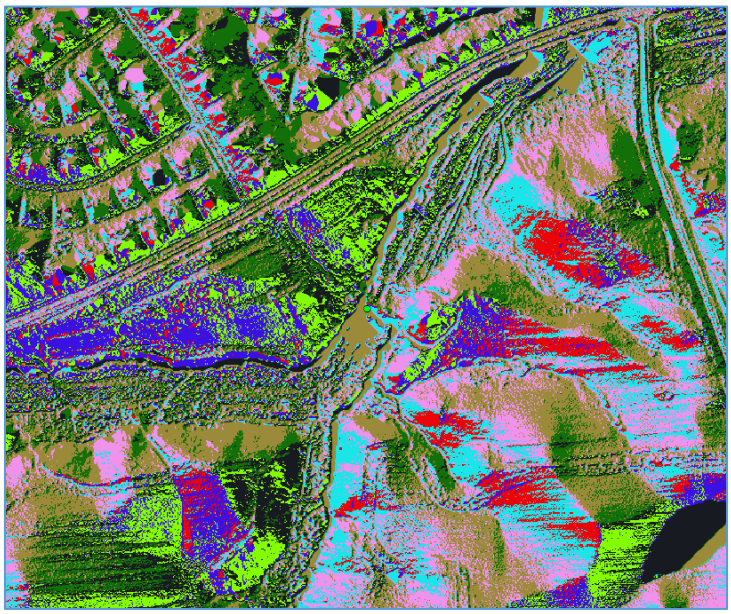
   Click OK

   The output values associated with the Flow Direction dataset are as follows:

   1 = East
   2 = Southeast
   4 = South
   8 = Southwest
   16 = West
   32 = Northwest
   64 = North
   128 = Northeast

32	64	128
16		1
8	4	2

(Image Source: ESRI)

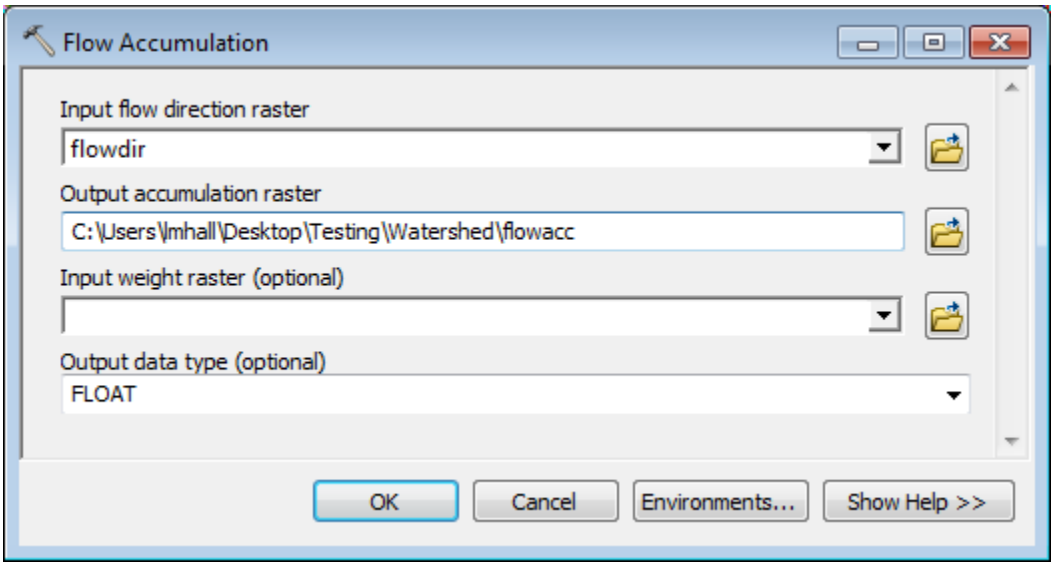


Flow Accumulation

1. Next, build a Flow Accumulation from our 'Flowdir' dataset. This process may take a few moments to complete…

   Search Tool> Flow Accumulation (Spatial Analyst)

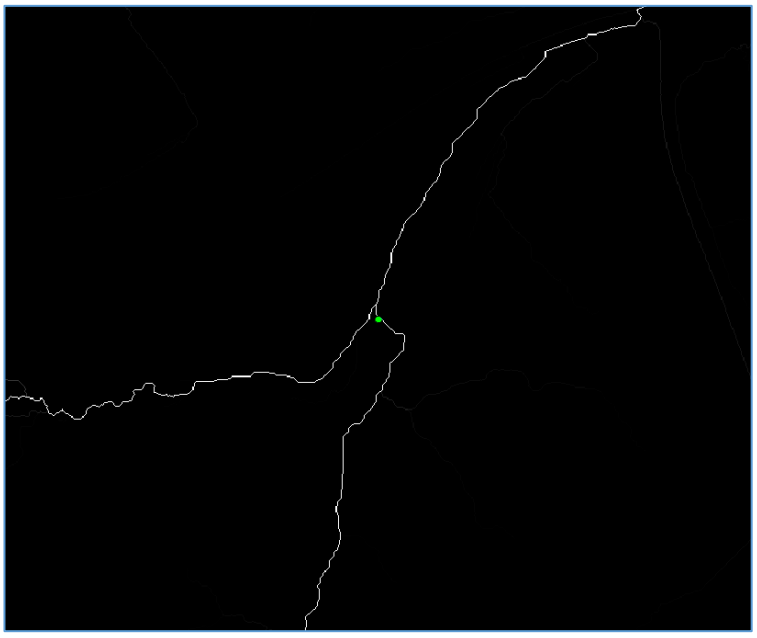
   Input flow direction raster: Flowdir
   Output accumulation raster: …\Testing\Watershed\flowacc



   Click OK

   The flow accumulation dataset is used to snap the pour point to the cell of highest accumulation.

   This flow accumulation dataset can also be used to generate stream networks and orders.



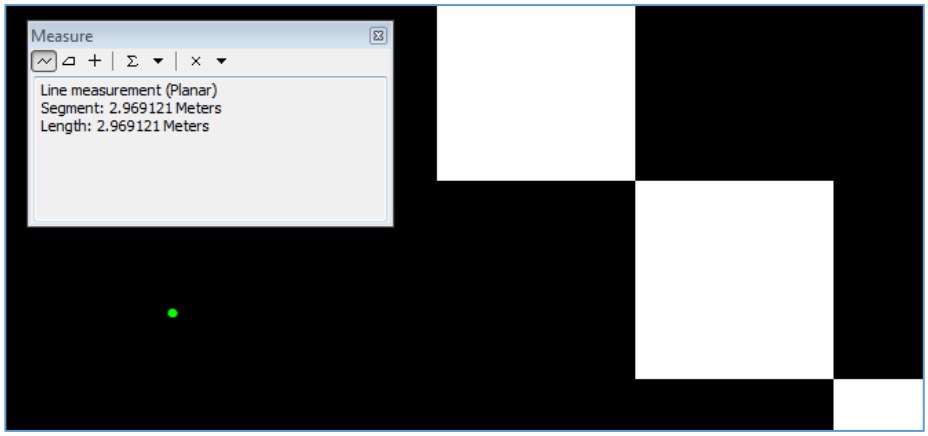
Snap Pour Point

1. Before proceeding, we need to determine the distance between our pour point and the closest cell of high accumulation.

   Zoom to your point feature (-76.815145, 38.868287) layer and set map scale to 1:25

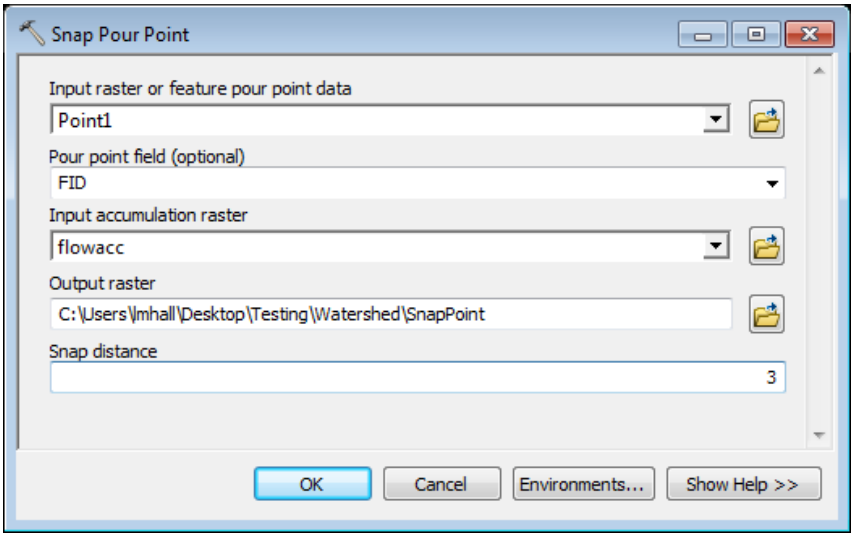
   Using the Measure ( ) tool measure the distance to the closest cell of high accumulation:

   ~ 3m



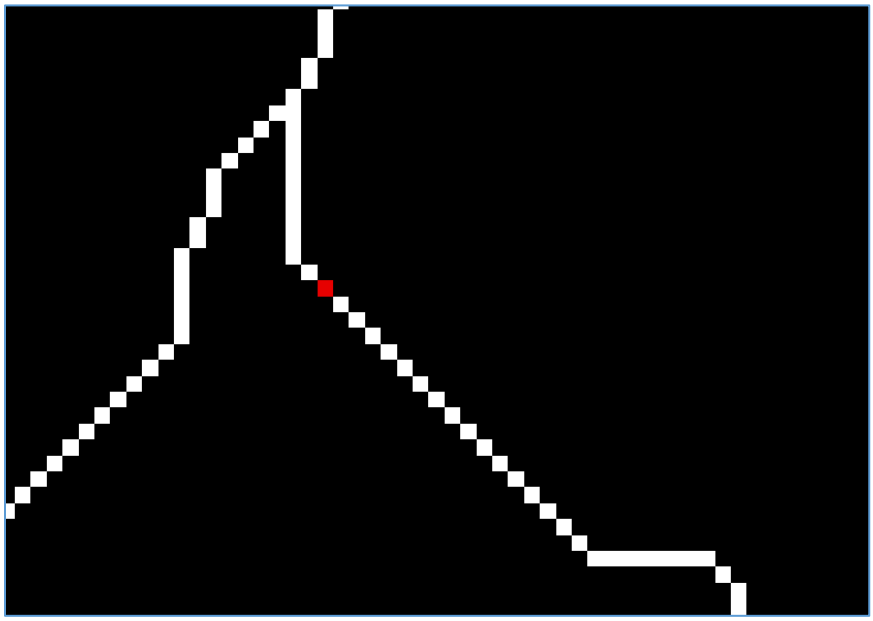
   Search Tool> Snap Pour Point (Spatial Analyst)

   Input raster or feature pour point data: Point1
   Pour point field: FID
   Input accumulation raster: Flowacc
   Output raster: …\Testing\Watershed\SnapPoint
   Distance: 3



   Click OK

Ensure your snap pour point cell is directly on top of a cell of high accumulation:



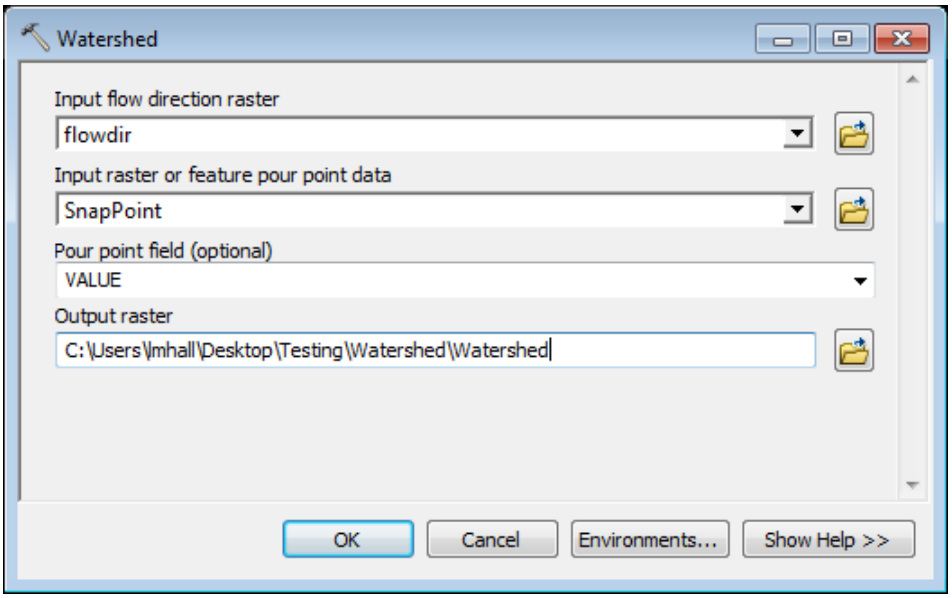
Our final process is delineating the watershed. Up to this point we have generated the necessary datasets for processing the watershed. It is recommended to not delete any of the processed datasets up to this point.

Watershed

1. With a flow direction dataset and a snapped pour point cell, we can generate a watershed:

   Search Tool> Watershed (Spatial Analyst)

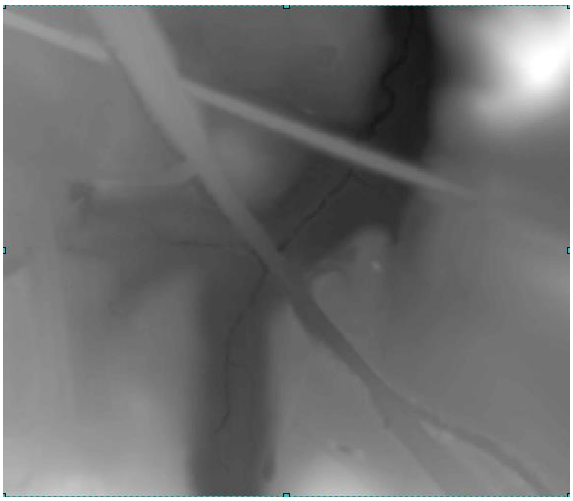
   Input flow direction raster: Flowdir
   Input raster or feature pour point data: Snappoint
   Pour point field: VALUE
   Output raster: …\Testing\Watershed\Watershed



   Click OK

Remove all layers but ‘Fill’ and ‘aoi’ from your map.

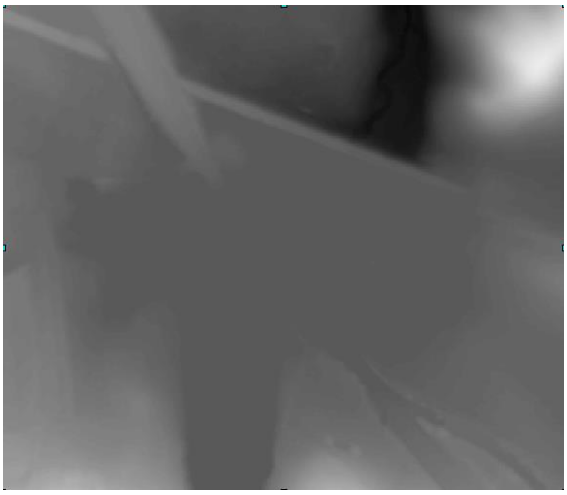
Zoom to the area west of our watershed:



The Fill tool processed this area as an unnatural sink.

The DEM is hydro-enforced, however this area either did not meet the requirements or was omitted from the breaklines.

The area in question could be a series of culverts along a stream, or running parallel to an old rail line.



Regardless, it is paramount to know your data!

This region was not part of our watershed analysis, however if you needed to include this stream you could process the DEM accordingly:

Create a polyline feature where ends land in the center of two cells in the stream on each side of the road/embankment. Add a field and set the value higher than that of the embankment.

Convert the polyline to a raster and using Raster Calculator, subtract this raster from the DEM.

(DEM_PG) – PolyRAS = BurnIn

Running the Sink/Fill tools again will allow the stream to flow through the new channel burned into the DEM.

ADDITIONAL RESOURCES

For more information about Maryland LiDAR, please visit the Maryland LiDAR Overview page

For more information about additional training opportunities, please visit the MD iMAP Training Overview page, or contact Lisa Lowe, Senior GIS Analyst with the Maryland Department of Information Technology, Geographic Information Office at lisa.lowe@maryland.gov.

For additional MD iMAP datasets, please visit the GIS Data Catalog

For all other inquiries related to Maryland LiDAR, please contact the GIO Office at service.desk@maryland.gov.